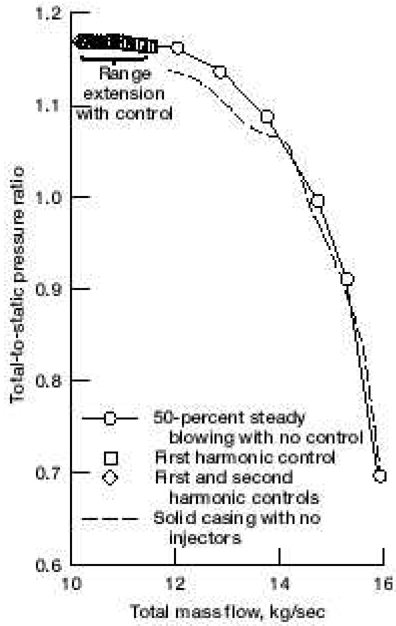
Jet Injection Used to Control Rotating Stall in a High-Speed Compressor

In a joint effort between the Massachusetts Institute of Technology (MIT) and the NASA Lewis Research Center, a new technology was demonstrated to identify and control rotating stall and surge in a single-stage, high-speed compressor. Through the use of high-velocity, high-frequency jet injectors, the instabilities of surge and stall were controlled in a high-speed compressor rig. Through the use of active stall control, modal instabilities that normally occur in the pressure measurements prior to stall were normalized and the range of the compressor was extended. Normally the events of rotating stall and surge instabilities limit the operation of the aeroengine compressor to a region below the surge line. To enhance the performance of the compressor, the Lewis/MIT team used active stall control methods to extend the normal operation of the compressor beyond the original stall point.

The single-stage transonic compressor facility at NASA Lewis was used in this demonstration. The compressor, NASA Stage 35, was run at tip Mach numbers of approximately 1.0 and 1.5. These operating conditions are similar to cruise and takeoff conditions in an aeroengine compressor. Through injection of high-velocity air through the compressor casing upstream of the rotor tip, the stalling mass flow of the compressor was reduced by 17 percent when operating at a tip speed of 1000 ft/sec. At a tip speed of 1475 ft/sec, the stalling mass flow was reduced by 4 percent beyond the normal stall point. This injected air was then oscillated to frequencies of nearly 450 Hz to cancel unsteady velocity perturbations forming in the compressor prior to rotating stall. This "active control" of the jet-injected air was used to further reduce the stalling mass flow by 8 percent over steady blowing at the 1000 ft/sec operating condition, and a 4-percent additional reduction was observed over steady blowing at the higher speed condition. These results were obtained by injecting less than 4 percent of the total compressor throughflow into the rotor tip region. The figure shows this marked increase in stall margin from the compressor maps. It shows the operation of the compressor under nominal operating conditions, with steady blowing, and with active control. These results mark the first successful demonstration of actively controlled air injection as a stall-control strategy for highly loaded compressors operating at speeds typical of an actual gas turbine engine.



Stabilized compressor characteristics at 70-percent speed with 1.5-percent injected mass flow rate.

To develop this capability for possible application on an engine, the Lewis/MIT team attempted active stall control of this high-speed compressor with both radial and circumferential inlet distortion screens present. In these distorted inflow cases, both steady blowing and active control of injected air provided increased stalling mass flow reductions from the aforementioned clean inlet case. These experimental results demonstrate a first-ever active control approach using jet injection to extend the stall margin in high-speed compressors. A near-term goal of this continuing research is to determine the combination of air-injection parameters and control strategies that are most effective in providing stall control for both clean and distorted inlet flow conditions. Mid-term research goals include demonstration of stall control in a multistage core compressor and development and application of either passive or active stall control strategies that will result in integral flight-worthy components of onboard engine hardware.

Bibliography

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Lewis contacts: Michelle M. Bright, (216) 433-2304, Michelle.M.Bright@grc.nasa.gov, and Dr. Anthony J. Strazisar, (216) 433-5881, Anthony.J.Strazisar@grc.nasa.gov
Authors: Michelle M. Bright, Dr. Anthony J. Strazisar, Harald J. Weigl, Zoltan

Spakovzsky, and James D. Paduano
Headquarters program office: OASTT
Programs/Projects: Propulsion Systems R&T, SGE, P&PM